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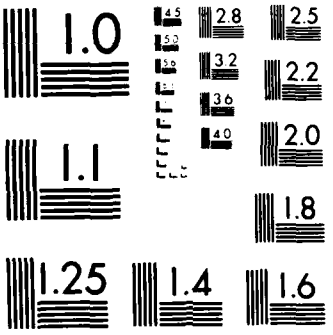
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DEVELOPMENT OF A NICKEL OXIDE/HYDROGEN MULTILAYER BIPOLAR BATTERY FOR PULSED POWER

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Spaced-based missile defense systems will require sources of pulsed power to operate prospective directed energy weapons. In principle, an electrochemical power source can provide this power at a much lower weight than alternative magnetic or electric field devices (capacitors or inductors). However, advances must be made in high rate thin film electrode materials and in battery design.

In the present program we are investigating electrochemical capacities under pulsed conditions for two promising materials: (1) $LaNi_5$ which acts as hydrogen storage anode with high hydrogen diffusion rates and (2) a hydrated nickel oxide cathode with optimized mixed ionic and electronic conductivity. Thin films were prepared by reactive sputtering, vapor desposition, anodization of nickel and electrochemical precipitation of nickel hydroxide.

The Phase I investigation emphasized thin nickel oxide films formed by reactive sputtering. As prepared, these films exhibited only low electrochemical activity which improved upon conditioning in the KOH electrolyte (Fig. 1). After oxidation only a part of the nickel oxide was reduced at 1.2V vs. RHE followed by substantial capacity at lower potentials. Thin films prepared by thermal evaporation of nickel oxide were electrochemically active without extensive activation. They proved to be more reversible than the sputtered films and the voltammogram (Fig. 1) closely resembled that of nickel oxides formed anodically on nickel surfaces. The rate capabilities of thin film electrodes were examined by measurements of current transients following potential steps from open circuit to 1.0V. Initial currents on sputtered, evaporated and anodically formed electrodes were 40, 80 and 350 mA/cm^2, respectively. This is in contrast to results obtained in this laboratory for most other reversible oxide electrodes, in which vacuum deposited thin films have equal or superior high rate performance. As-deposited materials were probably too dense and incompletely oxidized. Further modifications of sputtering conditions should provide more suitable material.

We also demonstrated the preparation of thin film $LaNi_5$ electrodes by rf sputtering. Maximum discharge rates of ~500 mA/cm^2 were obtained. The hydrides have superior storage density to oxides. Modifications of hydride structure and porosity will be sought which improve the kinetics of the H oxidation process, the H diffusion process, and the geometric roughness.

The capabilities of thin film nickel oxide metal hydride cells were defined and demonstrated using a small cell with the best presently available electrodes. The cell supplied trains of 100 1 msec power pulses into various loads. Initial power densities of 350 mW/cm^2 were obtained (Fig. 2). After optimization we anticipate that electrodes will be capable of >100 sequential pulses of 10^{-3} sec duration, before recharge, each pulse with a power density of 5 W/cm^2. Full multilayer bipolar batteries of 10^5 W/kg pulse could be constructed based on such performance.

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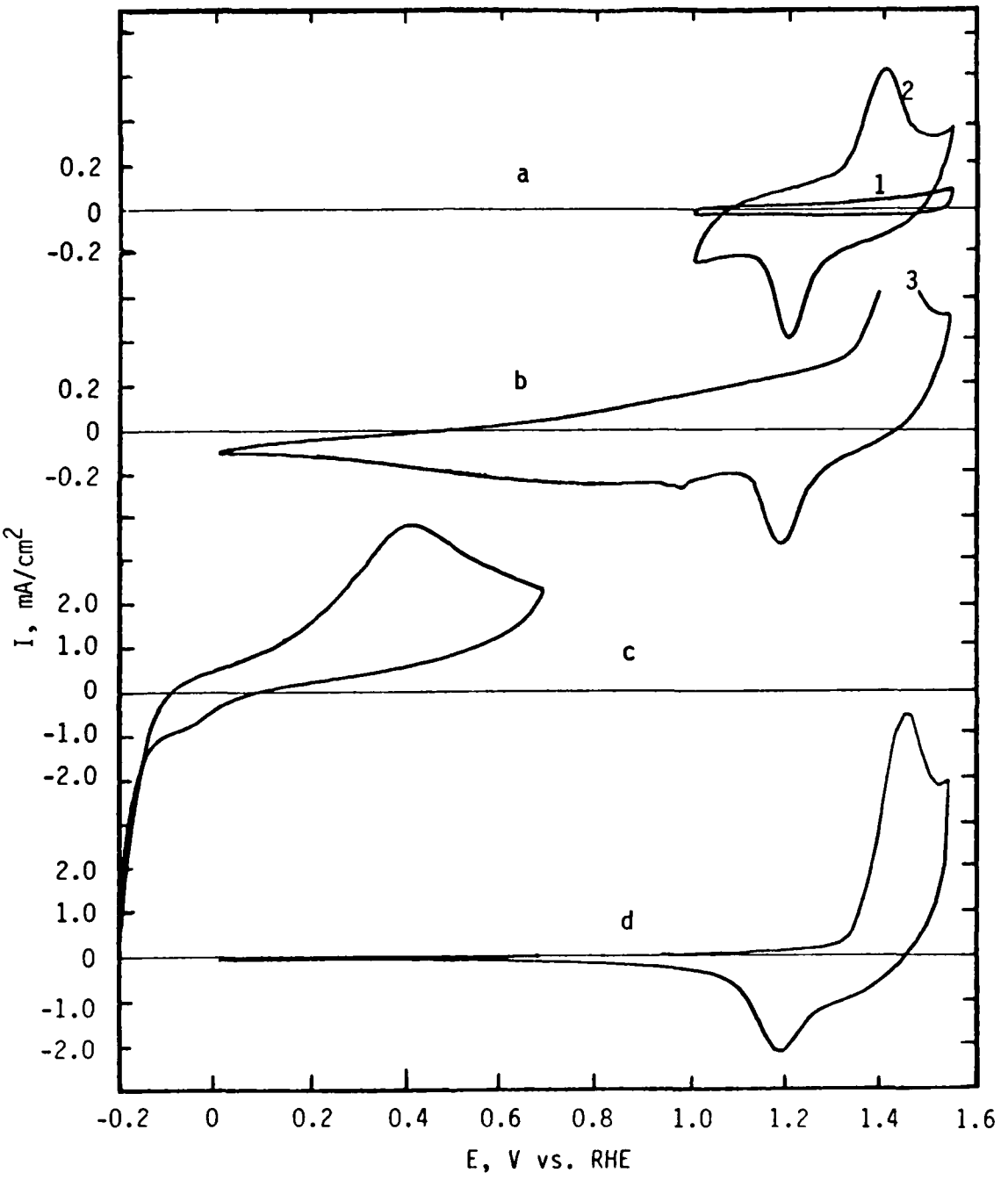

Fig. 1. Voltammograms of thin film nickel oxide and metal hydride electrodes. Sweep rate 20 mV/sec, 7.3M KOH. a and b, sputtered nickel oxide; 1, initial sweep, 2 and 3, after conditioning; c, $LaNi_5H_x$; d, thermally evaporated nickel oxide.

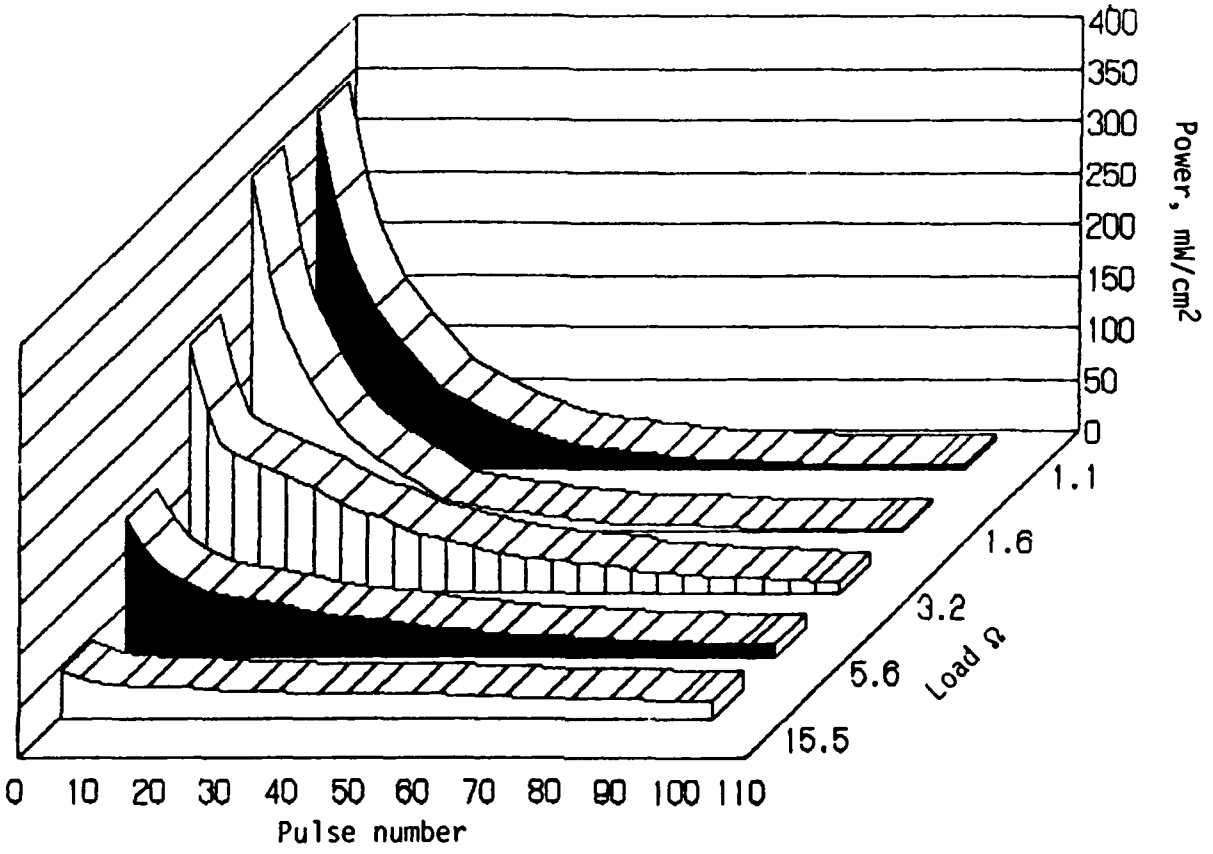

Fig. 2. Pulse discharge of a thin film $NiO_x/LaNi_5H_x$ cell, load applied for 1 msec at 1 msec intervals.

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